input of comparator 116, thereby lowering the switch current trip level and shortening the duty cycle of switch 110. When the voltage at terminal V_{SW} does not exceed the voltage at V_{IN} by at least the effective breakdown voltage of variable zener diode 130, transistor 820 does not conduct, and transistor 520 is turned off. At the same time, current source 522, shown in FIG. 5, provides a current of approximately 30 μA to the V input of comparator 116 which causes the voltage at the V input to increase, thereby raising the switch current trip level and consequently lengthening the duty cycle of switch 110.

While preferred embodiments of the invention have been set forth for purposes of the disclosure, modification of the disclosed embodiments may occur to those of skill in the art. For example, while the multi-function terminal feature of the present invention has been disclosed in the context of an integrated circuit for use in implementing a current-mode switching voltage regulator, it will of course be understood by those of skill in the art that the invention may be employed to implement a 5-terminal integrated circuit for use with voltage-mode switching voltage regulator topologies having a micro-power sleep mode capability.

Thus, a switching voltage regulator circuit including control circuitry, driver circuitry and a power switching device, capable of being implemented as an integrated circuit requiring only five terminals having multiple functions, including micro-power mode shutdown circuitry, and operable in a normal feedback mode as well as in an isolated flyback mode, has been disclosed. The invention can readily be packaged in a 5-pin power transistor integrated circuit package. One skilled in the art will appreciate that the present invention can be practiced by other than the described embodiments, which are presented for purposes of illustration and not of limitation, and the present invention is limited only by the claims which follow.

What is claimed is:

1. An integrated circuit for use in a switching voltage regulator circuit, the switching voltage regulator circuit providing a regulated voltage output at an output terminal, the integrated circuit including internal drive circuitry, a power switching transistor and control circuitry for varying the switching duty cycle of the switching transistor, the integrated circuit having at most five terminals including an input terminal, an output terminal a ground terminal and first and second function terminals for connection to discrete external components to implement the switching voltage regulator circuit, the integrated circuit comprising:

first means connected to one of the function terminals for accepting a feedback signal from the output of the switching voltage regulator circuit and for enabling the integrated circuit to operate in a first mode to regulate the output of the switching voltage regulator by varying the duty cycle of the switching transistor as a function of the magnitude of the feedback signal;

second means connected to the input and output terminals for enabling the integrated circuit to operate in an isolated flyback mode to regulate the output of the switching voltage regulator circuit as a function of a feedback voltage developed across a primary winding of a discrete external transformer; and

mode select means connected to one of the function terminals and to said first and second means to

disable the first means and to enable the second means in response to a disable signal applied to that function terminal by the discrete components.

2. An integrated circuit for use in a switching voltage regulator circuit providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for varying the on and off switching duty cycle of the switching transistor, and further having an input terminal, an output terminal, a ground terminal and first and second function terminals for connection to external components, the integrated circuit comprising:

first means connected to the first function terminal and to the control circuitry for accepting a first feedback signal indicative of the regulated output voltage, and for enabling the integrated circuit to operate in a normal feedback mode to regulate the regulated output voltage by varying the duty cycle of the switching transistor as a function of the magnitude of the first feedback signal;

second means connected to the input and output terminals and to the control circuitry for accepting a second feedback signal between the input and output terminals indicative of a voltage developed across a winding of an external transformer, and for enabling the integrated circuit to operate in a fully isolated flyback mode to regulate the regulated output voltage as a function of the magnitude of the second feedback signal; and

third means connected to one of the function terminals and to said first and second means to disable one of the first and second means and to enable the other in response to a control signal applied to that function terminal by external components.

3. The integrated circuit of claim 2, wherein said first means includes:

means for producing a first reference signal; and

means for detecting a difference between the first feedback signal and the first reference signal, and for generating an error signal indicative of that difference;

and wherein the control circuitry includes:

means for comparing the error signal to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal.

4. The integrated circuit of claim 2, wherein said second means includes:

means responsive to the second feedback signal for generating an error signal indicative of a difference between the second feedback signal and a predetermined threshold signal level;

and wherein the control circuitry includes:

means for comparing the error signal to a signal indicative of the magnitude of current conducted by the switching transistor, and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal.

5. The integrated circuit of claim 2, wherein said first means includes:

means for producing a first reference signal; and

means for detecting a difference between the first feedback signal and the first reference signal, and for generating a first error signal indicative of that difference;

wherein said second means includes:

means responsive to the second feedback signal for generating a second error signal indicative of a difference between the second feedback signal and a predetermined threshold signal level;

and wherein the control circuitry includes:

means for receiving the first and second error signals, for comparing at any given time one of the first and second error signals to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the compared one of the first and second error signals.

6. The integrated circuit of claim 3, wherein said means for generating an error signal includes a differential amplifier having a first input for receiving the feedback signal and a second input for receiving the first reference signal.

7. The integrated circuit of claim 4, wherein said means for generating the second feedback error signal includes:

an amplifier having a first input connected to one of the input and output terminals; and

means connected to a second input of said amplifier and to the other of the input and output terminals for establishing a threshold voltage, whereby a voltage differential is established across the inputs of the amplifier when a voltage difference between the input and output terminals exceeds the threshold voltage.

8. The integrated circuit of claim 7, wherein said means for establishing a threshold voltage includes a zener diode.

9. The integrated circuit of claim 8, wherein said zener diode has a zener breakdown voltage, and wherein said means for establishing a threshold voltage further includes:

means for establishing a trimming voltage in series with the zener breakdown voltage such that at least a part of the threshold voltage is comprised of the sum of the trimming and zener breakdown voltages; and

means connected to said means for establishing a trimming voltage, and to one of the function terminals, for varying the trimming voltage in response to a signal at that function terminal, thereby varying the threshold voltage.

10. The integrated circuit of claim 9, wherein said means for varying the trimming voltage is connected to the first function terminal.

11. The integrated circuit of claim 10, wherein:

said means for establishing a trimming voltage comprises a resistor; and wherein

said means for varying the trimming voltage varies a current conducted by said trimming voltage resistor as a function of a current conducted by the first function terminal.

12. The integrated circuit of claim 11, wherein the current conducted by the first function terminal is established at least in part by external components connected to the first function terminal.

13. The integrated circuit of claim 12, wherein the external components connected to the first function terminal includes a resistor connected to ground.

14. The integrated circuit of claim 2, wherein said third means is connected to the first function terminal.

15. The integrated circuit of claim 14, wherein the control signal is a current, and wherein said third means includes:

means for sensing the current conducted by the first function terminal; and

means responsive to said sensing means for disabling said first means and enabling said second means when the current sensed by said sensing means exceeds a predetermined threshold current.

16. The integrated circuit of claim 2, wherein said third means is connected to the first function terminal, and wherein the integrated circuit further comprises:

fourth means connected to the control circuitry and to the second function terminal for performing at least two of:

(a) frequency compensating the integrated circuit,

(b) limiting the peak current conducted by the switching transistor,

(c) variably limiting the current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit, whereby the current drawn by the integrated circuit is reduced.

17. The integrated circuit of claim 16, wherein said fourth means includes:

means for generating a signal indicative of the magnitude of current conducted by the switching transistor;

means connected to at least one terminal of the integrated circuit for sensing a feedback signal from the discrete components indicative of the magnitude of at least one of the regulated output voltage and the voltage developed across the winding of the external transformer, and for generating an error signal indicative of the difference between the feedback signal and a reference signal;

means for comparing the error signal to the current magnitude signal, and for turning off the switching transistor when the current magnitude signal exceeds the error signal; and

means for applying the error signal to the second function terminal, whereby the magnitude of the error signal may be controlled by a network of one or more external components connected to the second function terminal.

18. The integrated circuit of claim 17, wherein the network of external components connected to the second function terminal includes a frequency compensating capacitor.

19. The integrated circuit of claim 17, wherein the network of external components connected to the second function terminal includes a frequency compensation capacitor in series with a resistor.

20. The integrated circuit of claim 17, wherein the network of external components connected to the second function terminal prevents the error signal at the second function terminal from exceeding a predetermined maximum level, thereby limiting to a maximum peak value the magnitude of current conducted by the switching transistor.

21. The integrated circuit of claim 20, wherein the network of external components establishes a predetermined maximum voltage at the second function terminal.

22. The integrated circuit of claim 17, wherein the network of external components connected to the second function terminal variably controls the voltage at the second function terminal as a function of time,

thereby variably limiting as a function of time the current conducted by the switching transistor.

23. The integrated circuit of claim 22, wherein the network of external components for variably controlling the voltage at the second function terminal includes:

a resistor connected between a first node and a second node;

a capacitor connected between the second node and the ground terminal; and

means connected between the second node and the second function terminal for applying at least a portion of a voltage at the second node to the second function terminal, such that the voltage at the second function terminal upon application of a voltage at the first node gradually increases with time to gradually increase the current conducted by the switching transistor.

24. The integrated circuit of claim 17, the integrated circuit further having voltage regulator circuitry for providing a regulated voltage to at least portions of the internal drive circuitry, and wherein said fourth means further includes:

means for producing second reference signal;

means for comparing the second reference signal to a shutdown control signal applied to the second function terminal by the external components, and for generating a shutdown signal when the second reference signal and the shutdown control signal differ by a predetermined amount; and

means responsive to the shutdown signal for disabling at least the voltage regulator circuitry, thereby shutting down and reducing the current drawn by the integrated circuit.

25. The integrated circuit of claim 24, wherein the shutdown control signal is a voltage, and wherein:

said means for producing a second reference signal includes a diode having a first forward voltage drop; and wherein

said means for comparing the second reference signal to the shutdown control signal includes a transistor having a base-emitter circuit connected between said diode and the second function terminal, the base-emitter circuit having a second forward voltage drop which differs from the first forward voltage drop, and said transistor being adapted to disable the voltage regulator circuitry when the shutdown control signal voltage at the second function terminal is less than the difference between the first and second forward voltage drops.

26. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having a power switching transistor, circuitry for driving the switching transistor and control circuitry for varying the on and off switching duty cycle of the switching transistor, and further having for connection to external components an input terminal, an output terminal, a ground terminal and a function terminal, the integrated circuit comprising:

first means connected to the function terminal and to the control circuitry for accepting a first feedback signal indicative of the regulated output voltage, and for enabling the integrated circuit to operate in a normal feedback mode to regulate the regulated output voltage by varying the duty cycle of the switching transistor as a function of the magnitude of the first feedback signal;

second means connected to at least one of the terminals and to the control circuitry for accepting a second feedback signal indicative of a voltage developed across a winding of an external transformer, and for enabling the integrated circuit to operate in a fully isolated flyback mode to regulate the output voltage as a function of the magnitude of the second feedback signal; and

mode select means connected to the function terminal and to said first and second means to disable one of the first and second means and to enable the other in response to a mode select control signal applied to the function terminal by external components.

27. The integrated circuit of claim 26, wherein said first means includes:

means for producing a first reference signal; and

means for detecting a difference between the first feedback signal and the first reference signal, and for generating an error signal indicative of that difference;

and wherein the control circuitry includes:

means for comparing the error signal to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal.

28. The integrated circuit of claim 26, wherein said second means includes:

means responsive to the second feedback signal for generating an error signal indicative of a difference between the second feedback signal and a predetermined threshold signal level;

and wherein the control circuitry includes:

means for comparing the error signal to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal.

29. The integrated circuit of claim 26, wherein said first means includes:

means for producing a first reference signal; and

means for detecting a difference between the first feedback signal and the first reference signal, and for generating a first error signal indicative of that difference;

wherein said second means includes:

means responsive to the second feedback signal for generating a second error signal indicative of a difference between the second feedback signal and a predetermined threshold signal level;

and wherein the control circuitry includes:

means for receiving the first and second error signals, and for comparing at any given time one of the first and second error signals to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the compared one of the first and second error signals.

30. The integrated circuit of claim 27, wherein said means for generating an error signal includes a differential amplifier having a first input for receiving the first feedback signal and a second input for receiving the first reference signal.

31. The circuit of claim 28, wherein said means for generating the second feedback error signal includes:

an amplifier having a first input connected to one of the input and output terminals; and

means connected to a second input of said amplifier and to the other of the input and output terminals for establishing a threshold voltage, whereby a voltage differential is established across the inputs of the amplifier when a voltage difference between the input and output terminals exceeds the threshold voltage.

32. The circuit of claim 31, wherein said means for establishing a threshold voltage includes a zener diode.

33. The circuit of claim 32, wherein said zener diode has a zener breakdown voltage, and wherein said means of establishing a threshold voltage further includes:

means for establishing a trimming voltage in series with the zener breakdown voltage such that at least a part of the threshold voltage is comprised of the sum of the trimming and zener breakdown voltages; and

means connected to said means for establishing a trimming voltage, and to the function terminal, for varying the trimming voltage in response to a signal at the function terminal, thereby varying the threshold voltage.

34. The circuit of claim 33 wherein:

said means for establishing a trimming voltage comprises a resistor; and wherein

said means for varying the trimming voltage varies a current conducted by said trimming voltage resistor as a function of a current conducted by the function terminal.

35. The circuit of claim 34, wherein the current conducted by the function terminal is established at least in part by external components connected to the function terminal.

36. The circuit of claim 35, wherein the external components connected to the function terminal include a resistor connected to ground.

37. The circuit of claim 26, wherein said mode select means is connected to the function terminal.

38. The circuit of claim 37, wherein said mode select means includes:

means for sensing current conducted by the function terminal; and

means responsive to said sensing means for disabling said first means and enabling said second means when the current sensed by said sensing means exceeds a predetermined threshold current.

39. The circuit of claim 38, wherein the function terminal is connected to external components adapted to conduct a current which exceeds the threshold current.

40. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having a power switching transistor, circuitry for driving the switching transistor and control circuitry for varying the on and off switching duty cycle of the switching transistor, and further having at most five terminals for connection to external components consisting of an input terminal, an output terminal, a ground terminal and first and second function terminal, the integrated circuit comprising:

first means connected to the first function terminal and to the control circuitry for accepting a first feedback signal indicative of the regulated output voltage, and for enabling the integrated circuit to

operate in a normal feedback mode to regulate the regulated output voltage by varying the duty cycle of the switching transistor as a function of the magnitude of the first feedback signal;

second means connected to at least one of the input and output terminals and to the control circuitry for accepting a second feedback signal indicative of a voltage developed across a winding of an external transformer, and for enabling the integrated circuit to operate in a fully isolated flyback mode to regulate the regulated output voltage as a function of the magnitude of the second feedback signal;

mode select means connected to the first function terminal and to said first and second means to disable one of the first and second means and to enable the other in response to a mode select control signal applied to the first function terminal by external components; and

means connected to the control circuitry and to the second function terminal for enabling the switching voltage regulator circuit in response to signals applied to the second function terminal by a network of external components to be frequency compensated.

41. The integrated circuit of claim 40, wherein said first means includes:

means for producing a first reference signal; and

means for detecting a difference between the first feedback signal and the first reference signal, and for generating an error signal indicative of that difference;

and wherein the control circuitry includes:

means for comparing the error signal to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal.

42. The integrated circuit of claim 40, wherein said second means includes:

means responsive to the second feedback signal for generating an error signal indicative of a difference between the second feedback signal and a predetermined threshold signal level;

and wherein the control circuitry includes:

means for comparing the error signal to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal.

43. The integrated circuit of claim 40, wherein said first means includes:

means for producing a first reference signal; and

means for detecting a difference between the first feedback signal and the first reference signal, and for generating a first error signal indicative of that difference;

wherein said second means includes:

means responsive to the second feedback signal for generating a second error signal indicative of a difference between the second feedback signal and a predetermined threshold signal level;

and wherein the control circuitry includes:

means for receiving the first and second error signals, for comparing at any given time one of the first and second error signals to a signal indicative of the

magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the compared one of the first and second error signals.

44. The integrated circuit of claim 40, wherein said means for generating an error signal includes a differential amplifier having a first input for receiving the first feedback signal and a second input for receiving the first reference signal.

45. The circuit of claim 42, wherein said means for generating the second feedback error signal includes:

an amplifier having a first input connected to one of the input and output terminals; and

means connected to a second input of said amplifier and to the other of the input and output terminals for establishing a threshold voltage, whereby a voltage differential is established across the inputs of the amplifier when a voltage difference between the input and output terminals exceeds the threshold voltage.

46. The circuit of claim 45, wherein said means for establishing a threshold voltage includes a zener diode.

47. The circuit of claim 46, wherein said zener diode has a zener breakdown voltage, and wherein said means for establishing a threshold voltage further includes:

means for establishing a trimming voltage in series with the zener breakdown voltage such that at least a part of the threshold voltage is comprised of the sum of the trimming and zener breakdown voltages; and

means connected to said means for establishing a trimming voltage, and to one of the function terminals, for varying the trimming voltage in response to a signal at that function terminal, thereby varying the threshold voltage.

48. The circuit of claim 47, wherein said means for varying the trimming voltage is connected to the first function terminal.

49. The circuit of claim 48, wherein:

said means of establishing a trimming voltage comprises a resistor; and wherein

said means for varying the trimming voltage varies a current conducted by said trimming voltage resistor as a function of a current conducted by the first function terminal.

50. The circuit of claim 49, wherein the current conducted by the first function terminal is established at least in part by external components connected to the first function terminal.

51. The circuit of claim 50, wherein the external components connected to the first function terminal include a resistor connected to ground.

52. The circuit of claim 40, wherein said mode select means is connected to the first function terminal.

53. The circuit of claim 40, wherein said mode select means includes:

means for sensing current conducted by the first function terminal; and

means responsive to said sensing means for disabling said first means and enabling said second means when the current sensed by said sensing means exceeds a predetermined threshold current.

54. The integrated circuit of claim 39, wherein the network of external components connected to the second function terminal includes a frequency compensating capacitor.

55. The integrated circuit of claim 40, wherein the network of external components connected to the second function terminal includes a frequency compensation capacitor in series with a resistor.

56. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, and further having input and ground terminals for connection to a source of input power, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multifunction terminals for connection to external components adapted to apply control signals to the multi-function terminals, the integrated circuit comprising:

first means responsive to control signals applied to the first multi-function terminal, said first means including at least two of:
- (a) means for controlling the duty cycle of the switching transistor when the integrated circuit is operating in a normal feedback mode,
- (b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode, and
- (c) means for trimming a flyback voltage developed across a winding of an external transformer when the integrated circuit operates in a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for performing at least two of:
- (a) frequency compensating the integrated circuit,
- (b) limiting peak current conducted by the switching transistor,
- (c) variably limiting current conducted by the switching transistor as a function of time, and
- (d) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

57. The integrated circuit of claim 56, wherein said normal feedback mode controlling means includes:

means for producing a first reference signal;

means for generating a feedback mode error signal indicative of a difference between the first reference signal and a feedback signal applied to the first multi-function terminal indicative of the magnitude of the regulated output voltage;

means for comparing the feedback mode error signal to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal, whereby the duty cycle of the switching transistor is controlled as a function of the feedback signal.

58. The integrated circuit of claim 56, wherein said programming means includes:

means for controlling the duty cycle of the switching transistor when the integrated circuit operates in a fully-isolated flyback mode; and

means connected to the first multi-function terminal for sensing a mode-select signal at the first multi-function terminal and for responsively disabling said normal feedback mode controlling means and enabling said flyback mode controlling means.

59. The integrated circuit of claim 58, wherein said flyback mode controlling means includes:

means connected to the input and output terminals for receiving a flyback signal indicative of a voltage developed across the winding of the external transformer, and for generating a flyback mode error signal indicative of a difference between the flyback signal and a threshold signal level;

means for comparing the flyback mode error signal to a signal indicative of the magnitude of current conducted by the switching transistor; and

means responsive to the output of said comparing means for turning off the switching transistor when the current magnitude signal exceeds the error signal, whereby the duty cycle of the switching transistor is controlled as a function of the flyback signal.

60. The integrated circuit of claim 59, wherein said trimming means includes:

means connected to the first multi-function terminal for sensing a trimming control signal; and

means connected to said trimming control signal sensing means and to said flyback mode error signal generating means for trimming the magnitude of the threshold signal in response to the trimming control signal, thereby trimming the flyback voltage.

61. The integrated circuit of claim 56, wherein said second means includes:

means for generating a signal indicative of the magnitude of current conducted by the switching transistor;

means connected to at least one terminal of the integrated circuit for sensing a feedback signal indicative of the magnitude of at least one of the regulated output voltage and the voltage developed across the winding of the external transformer, and for generating an error signal indicative of the difference between the feedback signal and a reference signal;

means for comparing the error signal to the current magnitude signal, and for turning off the switching transistor when the current magnitude signal exceeds the error signal; and

means for applying the error signal to the second multi-function terminal, whereby the magnitude of the error signal may be controlled by a network of one or more external components connected to the second multi-function terminal.

62. The integrated circuit of claim 61, wherein the network of external components connected to the second multi-function terminal includes a frequency compensating capacitor.

63. The integrated circuit of claim 61, wherein the network of external components connected to the second multi-function terminal includes a frequency compensation capacitor in series with a resistor.

64. The integrated circuit of claim 61, wherein the network of external components connected to the second multi-function terminal prevents the error signal at the second multi-function terminal from exceeding a predetermined maximum level, thereby limiting to a maximum peak value the magnitude of current conducted by the switching transistor.

65. The integrated circuit of claim 62, wherein the network of external components establishes a predetermined maximum voltage at the second multi-function terminal.

66. The integrated circuit of claim 61, wherein the network of external components connected to the second multi-function terminal variably controls the voltage at the second multi-function terminal as a function of time, thereby variably limiting as a function of time the current conducted by the switching transistor.

67. The integrated circuit of claim 66, wherein the network of external components for variably controlling the voltage at the second multi-function terminal includes:

a resistor connected between a first node and a second node;

a capacitor connected between the second node and the ground terminal; and

means connected between the second node and the second multi-function terminal for applying at least a portion of a voltage at the second node to the second multi-function terminal, such that the voltage at the second multi-function terminal upon application of a voltage at the first node gradually increases with time to gradually increase the current conducted by the switching transistor.

68. The integrated circuit of claim 56, the integrated circuit further having voltage regulator circuitry for providing a regulated voltage to at least portions of the internal Circuitry, wherein said second means further includes:

means for producing a second reference signal;

means for comparing the second reference signal to a shutdown control signal applied to the second multi-function terminal by the external components, and for generating a shutdown signal when the second reference signal and the shutdown control signal differ by a predetermined amount; and

means responsive to the shutdown signal for disabling at least the voltage regulator circuitry, thereby shutting down and reducing the current drawn by the integrated circuit.

69. The integrated circuit of claim 68, wherein the shutdown control signal is a voltage, and wherein:

said means for producing a second reference signal includes a diode having a first forward voltage drop; and wherein

said comparing means includes a transistor having a base-emitter circuit connected between said diode and the second multi-function terminal, the base-emitter circuit having a second forward voltage drop which differs from the first forward voltage drop, and said transistor being adapted to disable the voltage regulator circuitry when the shutdown control signal voltage at the second multi-function terminal is less than the difference between the first and second forward voltage drops.

70. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, and further having input and ground terminals for connection to a source of input voltage and current, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals, the integrated circuit comprising:

first means responsive to control signals applied to the first multi-function terminal, said first means including:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit operates in a normal feedback mode,

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode, and

(c) means for trimming a flyback voltage developed across a winding of an external transformer when the integrated circuit operates in a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor,

(c) variably limiting current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

71. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, and further having input and ground terminals for connection to a source of input voltage and current, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals, the integrated circuit comprising:

first means responsive to control signals applied to the first multi-function terminal, said first means including:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit operates in a normal feedback mode,

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode, and

(c) means for trimming a flyback voltage developed across a winding of an external transformer when the integrated circuit operates in a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor, and

(c) variably limiting current conducted by the switching transistor as a function of time.

72. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, and further having input and ground terminals for connection to a source of input voltage and current, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor

into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals, the integrated circuit comprising:

first means responsive to control signals applied to the first multi-function terminal, said first means including:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit operates in a normal feedback mode, and

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor,

(c) variably limiting current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

73. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, and further having input and ground terminals for connection to a source of input voltage and current, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second function terminals for connection to external components adapted to apply control signals to the function terminals, the integrated circuit comprising:

first means responsive to a control signal applied to the first function terminal for controlling the duty cycle of the switching transistor as a function of the magnitude of the regulated output voltage; and

second means responsive to control signals applied to the second function terminal for:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor,

(c) variably limiting current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

74. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, and further having input and ground terminals for connection to a source of input voltage and current, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals, the integrated circuit comprising:

first means responsive to control signals applied to the first multi-function terminal, said first means including:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit operates in a normal feedback mode, and

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode;

second means responsive to control signals applied to the second multi-function terminal for:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor, and

(c) variably limiting current conducted by the switching transistor as a function of time.

75. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, the integrated circuit comprising:

at most five terminals for connection to external components, including input and ground terminals for connection to a source of input power, and output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals;

first means responsive to control signals applied to the first multi-function terminal, said first means including at least two of:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit is operating in a normal feedback mode,

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode, and

(c) means for trimming a flyback voltage developed across a winding of an external transformer when the integrated circuit operates in a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for performing at least two of:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor,

(c) variably limiting current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

76. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, the integrated circuit comprising:

at most five terminals for connection to external components, including input and ground terminals for connection to a source of input power, an output terminal for connection to external components adapted to convert the pulsed output of the switch-

ing transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals;

first means responsive to control signals applied to the first multi-function terminal, said first means including:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit is operating in a normal feedback mode,

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode, and

(c) means for trimming a flyback voltage developed across a winding of an external transformer when the integrated circuit operates in a fully-isolated flyback mode, and

second means responsive to control signals applied to the second multi-function terminal for:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor,

(c) variably limiting current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

77. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, the integrated circuit comprising:

at most five terminals for connection to external components, including input and ground terminals for connection to a source of input power, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals;

first means responsive to control signals applied to the first multi-function terminal, said first means including:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit is operating in a normal feedback mode,

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode, and

(c) means for trimming a flyback voltage developed across a winding of an external transformer when the integrated circuit operates in a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for performing at least two of:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor, and

(c) variably limiting current conducted by the switching transistor as a function of time.

78. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control cir-

cuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, the integrated circuit comprising:

at most five terminals for connection to external components, including input and ground terminals for connection to a source of input power, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals;

first means responsive to control signals applied to the first multi-function terminal, said first means including at least two of:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit is operating in a normal feedback mode, and

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for performing at least two of:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor,

(c) variably limiting current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

79. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, the integrated circuit comprising:

at most five terminals for connection to external components, including input and ground terminals for connection to a source of input power, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second function terminals for connection to external components adapted to apply control signals to the function terminals;

first means responsive to control signals applied to the first function terminal for controlling the duty cycle of the switching transistor as a function of the magnitude of the regulated output voltage; and

second means responsive to control signals applied to the second function terminal for:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor,

(c) variably limiting current conducted by the switching transistor as a function of time, and

(d) shutting down the integrated circuit,

[where] <u>whereby</u>

current drawn by the integrated circuit is reduced.

80. An integrated circuit for use in implementing a switching voltage regulator providing a regulated output voltage, the integrated circuit having internal drive circuitry, a power switching transistor and control circuitry for controlling the on and off duty cycle of the

switching transistor to produce a pulsed output, the integrated circuit comprising:

at most five terminals for connection to external components, including input and ground terminals for connection to a source of input power, an output terminal for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage, and first and second multi-function terminals for connection to external components adapted to apply control signals to the multi-function terminals;

first means responsive to control signals applied to the first multi-function terminal, said first means including:

(a) means for controlling the duty cycle of the switching transistor when the integrated circuit is operating in a normal feedback mode, and

(b) means for programming the integrated circuit to operate in one of a normal feedback mode and a fully-isolated flyback mode; and

second means responsive to control signals applied to the second multi-function terminal for performing at least two of:

(a) frequency compensating the integrated circuit,

(b) limiting peak current conducted by the switching transistor, and

(c) variably limiting current conducted by the switching transistor as a function of time.

81. An integrated circuit capable of implementing a current-mode normal feedback switching voltage regulator and a current-mode fully isolated flyback switching voltage regulator, the integrated circuit having a switching transistor, circuitry for driving the switching transistor, and control circuitry for controlling the on and off duty cycle of the switching transistor to produce a pulsed output, the integrated circuit comprising:

at most five terminals for connection to external components, including:

(a) input and ground terminals, connected to the integrated circuitry, for connection to a source of input voltage and current;

(b) an output terminal, connected to the switching transistor, for connection to external components adapted to convert the pulsed output of the switching transistor into the regulated output voltage;

(c) a first multi-function terminal responsive to control signals applied by external components connected to the first multi-function terminal for performing at least two functions selected from the group of:

(1) controlling the duty cycle of the switching transistor when the integrated circuit is operating in a normal feedback mode,

(2) programming the integrated circuit to operate in one of a normal feedback mode and fully-isolated flyback mode, and

(3) trimming a flyback voltage developed across a winding of an external transformer when the integrated circuit operates in a fully-isolated flyback mode; and

(d) a second multi-function terminal, responsive to control signals applied by external components connected to the second multi-function terminal, for performing at least two functions selected from the group of:

(1) frequency compensating the integrated circuit,

(2) limiting peak current conducted by the switching transistor,

(3) variably limiting current conducted by the switching transistor as a function of time, and

(4) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

* * * * *

Sub C1

82. An integrated circuit for implementing a current-mode switching voltage regulator circuit by connecting the integrated circuit to external components, the integrated circuit comprising:

at most five terminals, said terminals comprising input and ground terminals for connecting the integrated circuit to a source of input voltage and current, an output terminal for connecting the integrated circuit to an external inductive or transformer load, a feedback terminal for receiving an external feedback signal proportional to the regulated output voltage of the switching regulator, and a compensation terminal for connection to an external frequency compensation network;

a power switching transistor having its collector-emitter circuit coupled to conduct a current between the output terminal and the ground terminal;

means coupled to the switching transistor for varying the on and off duty cycle of the switching transistor in response to a control signal;

means including a resistive element coupled in series with the collector-emitter circuit of the switching transistor for generating a current sense signal indicative of the current conducted by the switching transistor;

means for generating an error signal indicative of a difference between the feedback signal and a reference signal;

means for coupling the error signal to the compensation terminal; and

means for comparing the current sense signal to the error signal and for generating the control signal to turn off the switching transistor when the current sense signal compares in a predetermined manner to the error signal to vary the

duty cycle of the switching transistor to produce the regulated output voltage.

Sub a1

83. The integrated circuit of claim 82, wherein the control signal is generated when the current sense signal equals or exceeds the error signal.

84. The integrated circuit of claim 82 further comprising:

means responsive to control signals applied to the compensation terminal for performing at least one of:

(a) limiting peak current conducted by the switching transistor,

(b) variably limiting current conducted by the switching transistor as a function of time, and

(c) shutting down the integrated circuit, whereby current drawn by the integrated circuit is reduced.

add a2